Heart matters

Cardiovascular events demand quick response

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photo by Audra Horton of Merkel EMS

"If the heart trembles, has little power and sinks, the disease is advancing … and death is near…"

- the Papyrus Ebers (circa 1550 BC)

Overview

Cardiovascular disease is a significant source of morbidity and mortality in the United States with estimates of a half-million deaths per year attributed directly to sudden cardiac death.[1] Another three quarters of a million people will require resuscitation attempts during hospitalization.[2] Although treatment algorithms have been continuously revised over the last 30 years, the hospital admission rate among patients who undergo resuscitation in

TABLE 1	1975	1995	P value*
Prevalence of ventricular fibrillation or tachycardia	42%	28%	0.21
Prevalence of asystole or pulseless electrical activity as the first documented rhythm	58%	72%	.021
Survival to hospital discharge	22%	9%	.007

*The p-value is a term that represents statistical significance, or the probability that the observed effect could have been obtained by chance. In many clinical trials, the results would be considered statistically significant if the p-value is less than or equal to 0.05.

Given a p-value of 0.05, if a particular study were to be conducted 100 separate times, the same results would occur 95 times, and different results would occur only 5 times

the field remains very low and even fewer are discharged neurologically functional.[3-8]

In a study published in 1998, researchers in Los Angeles compared cardiac arrest survival rates from the year 1995 to the year 1975.[9] During that twenty-year period, the Los Angeles EMS world saw the introduction of 9-1-1 access, the concept of an emergency medical dispatcher, endotracheal intubation, first responders with automated external defibrillators, a transition away from hospital radio telemetry contact toward standing orders and the development of the American Heart Association ACLS algorithms.

The data showed a statistically significant decrease in survival to hospital discharge despite all the advances made during that time (Table 1).

Despite the fact that the modern form of CPR has been around for almost half a century,[10] no significant increases in survival rates have been reported for over thirty years.[7] When examining the characteristics of resuscitation during that time, most of the changes have been at the advanced level. Based on that observation, two important questions emerge.

1. If advanced care is not improving survival rates from cardiac arrest, why continue to do it?
2. Could there still be some undiscovered basic principle of cardiac arrest resuscitation that prevents the advanced care from working?

Clearly, a change has to be made.

The Chain of Survival

The American Heart Association's Emergency Cardiovascular Care programs emphasize a series of steps which must be performed as quickly as possible. These steps are collectively known as the Chain of Survival.[11]

The first link in the chain is early access. If the warning signs of an impending cardiac arrest (such as chest pain and shortness of breath) are recognized and emergency medical care is accessed early, it may be possible to avoid the arrest altogether. In situations where the signs are not recognized or no warning signs occur, early recognition of the collapse and access to the 9-1-1 system is critical.

The second link in the chain is early CPR. CPR is most effective when started immediately after the collapse. The chances of successful resuscitation double when bystanders perform CPR prior to the arrival of EMS.

The third link in the chain of survival is early defibrillation. For most adult victims of non-traumatic cardiac arrest, ventricular fibrillation is most often the initiating dysrhythmia. The interval from collapse to first shock is the single greatest determinant of survival.[12] For every minute that passes while the patient is in ventricular fibrillation (V-fib), survival decreases by 7 percent to 10 percent.[13]

The only therapy that will successfully terminate V-fib is electrical shock or countershock. Obviously, this can only be accomplished by having the defibrillator with you and in a state of readiness. If you encounter a cardiac arrest victim and the defibrillator is not immediately available, the time it takes to get it and come back will waste precious minutes the patient might not be able to spare.

A fibrillating myocardium is consuming energy faster than even perfect CPR can replace it. At about 10-12 minutes of fibrillation, the entire energy reserves of the myocardium will be depleted and it will be impossible to stimulate the heart to beat again. Fibrillation must be terminated while there is still enough energy remaining within the myocardium to produce muscle contraction.

In the prehospital environment, ventricular fibrillation is generally not the

most common initial rhythm.[14] Medics far more often encounter asystole or a bradyasystolic rhythm. This does not mean that ventricular fibrillation is infrequent in prehospital cardiac arrests, but rather, EMS generally does not arrive soon enough to see it.

Advanced cardiac life support is the final, although admittedly weakest, link in the chain.[9] Paramedics providing advanced life support measures at the scene can contribute to overall survival rates for out-of-hospital cardiac arrest. In the best of circumstances, however, if pulse restoration does not occur within 15 minutes from collapse into cardiac arrest, the patient will not survive.

Three-Phase Model of Ventricular Fibrillation

Recent evidence has suggested that providing immediate shocks to newly discovered ventricular fibrillation may not be adequately serving all patients. Ventricular fibrillation may actually progress through three distinctively separate phases each with its own optimal management strategy.[15]

The "Electrical Phase" starts when the fibrillation begins and lasts for about four minutes. During this period, the heart muscle has not had time to develop significant ischemic injury.[16] The therapy that appears to offer the greatest benefit for these patients is early defibrillation. Whether CPR is delivered during this phase does not seem to affect morbidity and mortality.[16]

The "Circulatory Phase" begins at about the four-minute mark and lasts for an additional six minutes. During this second phase, tissue injury begins within the heart muscle following depletion of metabolic reserves, accumulation of toxic metabolites, and the initiation of the ischemic cascade. All of these factors contribute to the ability of the heart to respond to various therapies, including a countershock. Administration of some interval of chest compressions before any attempt at defibrillation appears to improve the outcome for patients who have reached this phase.[16-18]

The final "Metabolic Phase" begins about ten minutes after the onset of fibrillation. At this point, irreversible cellular damage has developed. Myocardial cells that have managed to survive this long have been rendered too weak to recover. In fact, restoration of normal blood flow into this weakened area, if not undertaken properly, may lead to additional reperfusion injury. No therapy has yet been identified which improves the outcome for patients who have entered into the metabolic phase of ventricular fibrillation.

Management

As with any medical procedure, always follow your medical director's protocols. One way to manage a cardiac event is to begin your assessment by establishing unresponsiveness, calling for additional help if needed, and getting a defibrillator to the patient's side as quickly as possible. During the general survey of the patient and the scene, determine if a resuscitation attempt is appropriate. In any situation where the possibility of life exists, EMS personnel should make an intense resuscitation effort.

Manually open the airway. Look, listen and feel for any respiratory effort. If the patient is not breathing normally, ventilate with a BVM and 100 percent oxygen. Establish pulselessness and begin CPR. Apply a cardiac monitor or AED and analyze the rhythm.

If EMS personnel witness the start of the fibrillation, delivery of a single countershock may be more beneficial than even chest compressions. The optimal energy setting necessary for successful conversion is still unknown.[12] For agencies using monophasic defibrillators, the American Heart

Association recommends a 360-joule energy setting for the first and each subsequent shock.[12]

For agencies with biphasic waveform defibrillators (the standard since the year 2000), deliver a first shock energy level between 120 and 200 joules.[12] EMS agencies should check with the defibrillator manufacturer to determine the optimal energy level for their particular machine. If there is a delay in getting to the defibrillator however, CPR should be initiated as quickly as possible.

In situations where the start of fibrillation was not witnessed by EMS personnel, immediate defibrillation may not be the most appropriate therapy. Instead, medics should delay the shock and begin high-quality CPR as quickly as possible. High quality CPR is achieved when:

- chest compressions are deep and fast;
- rescuers allow the chest to fully recoil following compression; and
- interruptions in compressions are minimized.

Following five cycles, or roughly two minutes of CPR, medics should deliver a single countershock at the energy settings previously discussed.

The use of three stacked shocks in the initial management of ventricular fibrillation is no longer recommended.[19] The original need for the three-shock sequence was based on conversion rates. The old-style monophasic defibrillators often required a series of three shocks in order to achieve a 90 percent successful conversion rate. Current biphasic technology is capable of achieving 90 percent conversion rates with a single shock.[20]

Regardless of whether the witnessed arrest received the countershock first or the non-witnessed arrest received CPR before the countershock, all defibrillation attempts should be followed by an immediate two-minute period of high-quality CPR.[19] EMS personnel should not waste time checking for pulses or analyzing for a rhythm conversion. As soon as the shock is administered, deliver a two-minute period of CPR beginning with chest compressions. A rhythm check can occur at the end of the CPR period.

It has been demonstrated that even in situations where rhythm conversion has occurred, the fibrillation period has left the heart too weakened to maintain effective blood flow.[21] A period of chest compressions following the countershock will enhance blood flow produced by the weakened myocardium and give the heart an opportunity to regain strength. There is no evidence that compressing the chest and heart of a patient who has just been successfully defibrillated is harmful.[19]

During the initial two-minute period of CPR, EMS personnel may begin advanced procedures; however, advanced care should never be allowed to interfere with high-quality CPR or countershocks. No link has been established between prehospital advanced care and survival from cardiac arrest.[19]

The American Heart Association no longer considers early insertion of an endotracheal tube to be the goal of all resuscitation attempts.[22] Supraglottic airways, such as Combitubes and the LMA may be considered as acceptable alternatives to the endotracheal tube and may even be preferable in some cases. EMS personnel may also ventilate with a BVM and defer insertion of an advanced airway until the patient has regained spontaneous circulation or failed to respond to countershocks and several periods of CPR.[22]

Advanced life support therapy for medical CPR cases should be performed exactly where the patient is found,

assuming there is no risk of harm to the patient or EMS personnel by remaining at that location. Moving medical CPR patients early in the resuscitation phase interrupts CPR and diminishes the chances of recovery.

As soon as IV access has been achieved, one of two vasopressors may be administered. Epinephrine 1:10,000 is commonly used and may be administered by IV push in 1 mg boluses repeated every three to five minutes for the duration of the arrest.[19] The hormone vasopressin may be substituted for either the first or second epinephrine and is given in 40 mg (units) IV push.[19] The vasopressors will not convert the fibrillation, but they may create a situation whereby the defibrillation attempts are more effective.

At the end of this two-minute period of CPR, EMS providers should check the ECG rhythm. If the patient remains in fibrillation, attempt defibrillation again with a single countershock at either the same energy setting or the next higher setting. There is no available evidence to suggest that escalating energy levels are any more effective than non-escalating energy levels and either strategy can be used safely and effectively.[12] As soon as the countershock is delivered, resume CPR immediately beginning with chest compressions.

If the patient remains in ventricular fibrillation after two or three shock/CPR cycles and vasopressor use, medics may administer an antiarrhythmic. Amiodarone is recommended as the first-line antiarrhythmic medication, however lidocaine is an acceptable alternative.[19] Amiodarone is a complex drug that acts on the sodium, potassium, and calcium channels as well as possessing some alpha and beta-blocker properties.[19] The usual first dose of amiodarone is 300-milligrams IV or IO push.[19] If there is no conversion within five minutes, a single subsequent dose of 150 mg is acceptable.[19]

If lidocaine is used, the recommended dose is 1.0 to 1.5 milligrams per kilogram as an IV or IO bolus.[19] Repeat doses of lidocaine in three to five minutes if there is no response.[19] It is important to note, however, that there is no evidence that any of the antiarrhythmics positively influence the survival-to hospital discharge of cardiac arrest victims when compared to countershocks only.[19]

Continue to provide single countershocks as needed, followed by two minute periods of high quality CPR. During the CPR periods, continue to provide epinephrine and an antiarrhythmic at three to five minute intervals.

If at any time the patient regains a pulse, a reassessment of the airway, breathing and circulatory status should occur.[23] A blood pressure should be obtained as quickly as possible. If the patient is found to be hypotensive, a single fluid bolus of 250-500 mL of normal saline in considered appropriate.[23] The blood pressure should then be reassessed for response. If needed, a vasoactive medication, such as dopamine or norepinephrine may be administered.

The Future of Resuscitation

Currently, research is underway to find ECG signal characteristics that can be used to aid in the delivery of fewer but more effective countershocks. One such characteristic, derived from fractal geometry, is called the scaling exponent.[24] The scaling exponent characterizes the “roughness” or “smoothness” of the VF waveform and expresses that characteristic as a number between 1 and 2.[24]

The exponent is calculated by a microcomputer inside the defibrillator or AED. Early, retrospective studies using data from AEDs carried by seven police departments in suburban Pittsburgh suggest that the scaling exponent can be used to predict the likelihood of successful

defibrillation.[25] In the not-too-distant future, the scaling exponent may help guide the resuscitation attempts both in and out of the hospital.

Summary

The majority of adult cardiac arrest victims develop ventricular fibrillation as the cause of their collapse. Every minute that passes from the moment of collapse until the patient is successfully brought out of fibrillation, the chances of survival decrease by about 10 percent. The only intervention that has been proven to convert ventricular fibrillation to a perfusing rhythm is a successful countershock. Evidence exists which suggests that ventricular fibrillation may actually progress through three distinctively separate phases. An interval of CPR prior to the delivery of a countershock may provide survival advantages in some patients.

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